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Hydrogeologic Inventory of the upper Illinois River Basin – Creating a large data base from well construction records

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Abstract

A large data base consisting of 40,679 well locations and 196,687 lithologic records was created from Illinois, Indiana, and Wisconsin well construction records for wells drilled during the period 1980-1997. The purpose of the data base is to provide information for mapping the surface, thickness, transmissivity and hydraulic conductivity of the Quaternary, Silurian/Devonian, and Cambrian/Ordovician age aquifers in the upper Illinois River Basin (UIRB). These digital maps and information will be used for the UIRB study of the National Water-Quality Assessment Program, U.S. Geological Survey (USGS), to facilitate county- or basin-wide three-dimensional (3-D) ground-water flow and transport modeling. A geographic information system (GIS) was used to create and manage the data base. Over 50 computer programs were written and utilized to compile and summarize data from various sources.

The challenges of creating this large hydrogeologic data base were in assembling the differently formatted data from diverse sources and in summarizing the data for application to 3-D ground-water flow and transport modeling. The first challenge was dealing with differently formatted data. The data consisted of location, lithologic, construction, and aquifer-test information for 40,736 wells (203,286 lithologic records) and were obtained from Illinois State Geological Survey (ISGS), Indiana Department of Natural Resources (IDNR), and Wisconsin Department of Natural Resources (WDNR). Only wells with complete locational information and lithologic records were included in the data base (fig. 1). There were 34,373 wells from Illinois, 6,175 wells from Indiana, and 131 wells from Wisconsin. The amount of data from WDNR was limited because, at the time the data was obtained (1997), paper well records only were recently compiled into a digital data base. A total of 196,687 complete lithologic records were available from the three agencies. Different data base layouts and formats are used by the three agencies. Major differences in the data were order of presentation, units of measurement, and types of recorded information. Because of these differences, some data had to be reformatted, calculated from existing data, or re-ordered so that it could be uniformly compiled into one data base. The large size of this data set made it difficult to rearrange data columns and to process because each processing step took multiple days of run-time on the computer. In addition, each agency had a different method for retrieving data from their data bases. ISGS required township and range locations, IDNR required spatial polygons defining the area of interest, WDNR required county names. Because of the different data-retrieval requirements, the outer edges of the UIRB were not adequately covered by wells (fig. 1). The few wells available from Wisconsin also provided relatively poor coverage of the Wisconsin portion of the basin.

The lithologic data from each agency were compiled into related data files and three digital maps were made from the locational information. Different well-numbering systems were used by each agency to uniquely identify the wells in their data bases. To create a unified data base, unique USGS-format well-identification numbers were assigned to each well. The information associated with each digital map was placed in the same format and map projection and the maps were joined digitally. After reformatting and joining the related files, the well information in the data base included: IDNR well identification (ID) number, ISGS American Petroleum Institute (API) well ID number, WDNR well ID number, construction date, longitude, latitude, Universal Transverse Mercator (UTM) zone 16 x-coordinate, UTM zone 16 y-coordinate, Lambert x-coordinate, Lambert y-coordinate, State Plane x-coordinate, State Plane y-coordinate, township, township direction, range, range direction, section, topographic quadrangle name, FIPS state and county code, State name, County name, hydrologic unit code, land-surface altitude, well depth, water level, discharge, pump time, drawdown, casing length, casing top, casing bottom, casing diameter, screen length, screen top, screen bottom, screen diameter, lithologic records from well construction (depth to top and bottom of lithology and lithologic description).

The second challenge was summarizing the data for mapping and use in hydrogeologic models. For each well location there are many lithologic records that describe the stratigraphy that the well penetrates. To summarize the information, lithologic ages were estimated and depths to the top of the Silurian/Devonian, and Cambrian/Ordovician aquifers were identified. The data recorded for each well provided different information about the various aquifers because not all wells penetrated each aquifer (table 1).

The lithologic descriptions were inconsistent among wells from the three agencies and also within a particular agency. Various word combinations were pattern-matched to create a common descriptor for each lithology. Once consistent lithologic descriptors were established, each descriptor was attributed with an aquifer code that described the material as unconsolidated or bedrock. A quality check was performed to ensure that aquifer codes were in a logical sequence. For example, ensure that no unconsolidated material is listed in the related lithologic data file as being present underneath bedrock material. Errors in the sequence of lithologic records, such as the top of an underlying lithology listed as above the bottom of the overlying lithology, were identified and corrected manually. After examining hundreds of lithologies, patterns in descriptions became apparent and these patterns were used to help identify correct sequences.

To facilitate correcting the sequence of lithologies and later identifying the lithologic age, a stratigraphic table was compiled based on the "Handbook of Illinois Stratigraphy" (Willman and others, 1975), "Compendium of Rock-Unit Stratigraphy in Indiana" (Shaver and others, 1970), "Bedrock Geologic Map of Indiana" (Gray and others, 1987), "GEOLEX Data base—National Geologic Map Data Base" (U.S. Geologic Survey, 1999), and "Hydrogeologic Atlas of Aquifers in Indiana" (Fenelon and others, 1994). The stratigraphic table did not include Wisconsin lithologic units because the formation and age of lithologies for wells in Wisconsin were identified previously by WDNR. The compiled stratigraphic table included group/series and formation name, age, approximate thickness, description of color and texture, and spatial extent.

Ages associated with a lithology were identified after the stratigraphic table was compiled. Because a goal was to map the top of the Silurian/Devonian, and Cambrian/Ordovician aquifers and thickness of the Quaternary and Silurian/Devonian aquifers, emphasis was placed on identifying the lithology of age-specific aquifers. Formations were identified, when possible. If formations could not be identified, the lithology was attributed with 'unidentified' formation. All lithologies with an aquifer code of 'unconsolidated' were attributed as 'Quaternary' age and 'undifferentiated' formation. The more difficult task was determining which bedrock lithologies were Silurian/Devonian and which were Cambrian/Ordovician. In parts of the UIRB, Mississippian/Pennsylvanian bedrock also is present. To aid in identifying bedrock lithologies of a specific age, the uppermost bedrock was needed to provide a starting point.

Uppermost bedrock age and formations previously have been mapped in Illinois (Willman and others, 1975), Indiana (Gray and others, 1987), and Wisconsin (Wisconsin Geological and Natural History Survey, 1981). A new map was compiled from these State maps to show uppermost bedrock age and formation in the UIRB (Arnold and others, 1999; fig. 4). This map provided a gross definition of the age of the uppermost bedrock. Wisconsin lithologic records contained formation and age recorded by the WDNR. Therefore, these Wisconsin lithologic records were not examined during the process of identifying formations and ages for the data base. Every record in the lithologic data file for each well was examined and the first entry of bedrock material was identified as the top of the bedrock surface and attributed with the age and formation of the uppermost bedrock. For the wells that ended in bedrock material, the lithologies of each well were attributed interactively with formation and age. In most cases, identification of ages was straight-forward and formation names easily followed the compiled stratigraphic table. However, some lithologic records did not agree with the map of uppermost bedrock (probably because of map scale). If a lithology could not be associated with the stratigraphic table and map of uppermost bedrock, the formation was attributed as 'undifferentiated' or 'unknown' and the age was estimated by the lithologies above and below the unidentified one. Marker beds, such as the Maquoketa Shale, indicated where the age of the bedrock material changed. However, these marker beds are not always present. When the marker beds couldn't be identified from the lithologic records, age was recorded as 'unknown' and formation was recorded as 'unidentified'.

To calculate the hydraulic properties (transmissivity and hydraulic conductivity), several pieces of information were required: duration of aquifer test, well discharge, drawdown during pumping, well diameter, screen length, and aquifer thickness. The thickness of permeable material in each aquifer was calculated to estimate aquifer thickness. Wells without the required information were not used in transmissivity and hydraulic conductivity calculations. Some of the wells had incorrect or missing well-construction information. In order to include as many wells as possible with sufficient information for calculating the hydraulic properties, the well construction information was added or corrected, if possible, based on available information about the well.

After all information was summarized, geostatistical software was used to evaluate and statistically model spatial structure of the Silurian/Devonian and Cambrian/Ordovician aquifer surfaces and the thickness of the Quaternary and Silurian/Devonian aquifers. Results of the geostatistical modeling provided statistically unbiased estimates of depth to the top of the Silurian/Devonian and top of the Cambrian/Ordovician aquifers; and thickness of the Quaternary and Silurian/Devonian aquifers. The software also was used to make preliminary maps of the transmissivity and hydraulic conductivity of each aquifer. Prediction standard error maps were utilized to identify regions characterized by differing amounts of uncertainty.

Developing a hydrogeologic data base of this size is a long process that requires careful planning. Most important in data base development is that the interpretation of lithologies and assumptions are made under the supervision of an experienced geologist. Well construction records are neither the most consistent nor accurate source of geologic information but they are the most geographically wide-spread snapshot of underlying geology. The advantage of using well construction information over drilling additional wells is the lower cost. The only cost of using existing data is that of the data itself and personnel time for processing the data into a comprehensive geologic data base. Once the data base is made, it can be used for 3-D modeling in a variety of applications.

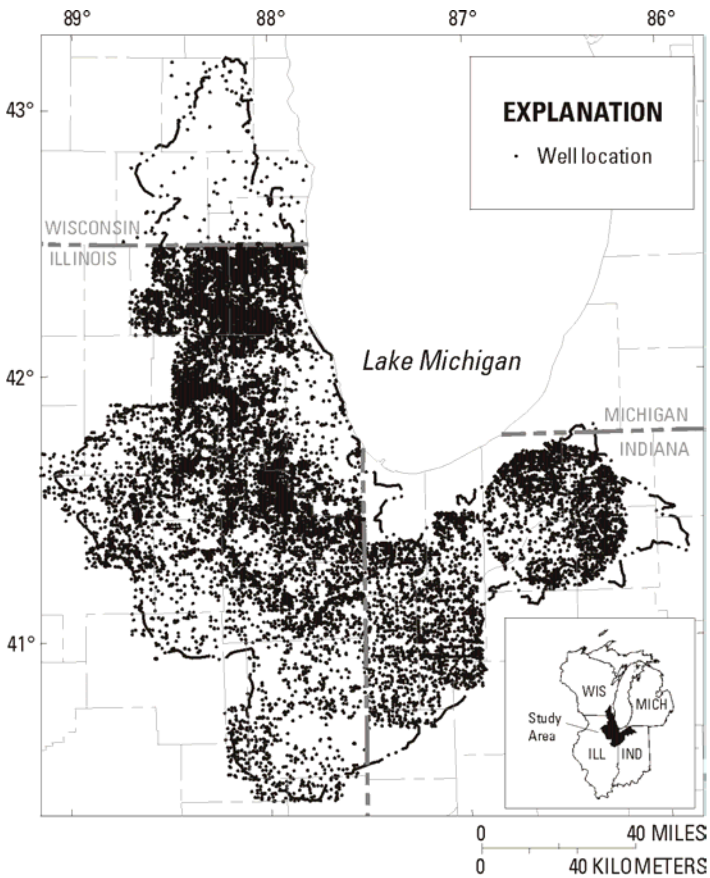

Figure 1. Location of wells included in the hydrogeologic data base of the upper Illinois River Basin.

Table 1. Information provided by wells in the hydrogeologic data base.

Information Provided	Number of Wells	Percent of Wells in Data Base
Depth to top of Silurian/Devonian aquifer	17,000	42%
Depth to top of Cambrian/Ordovician aquifer	6,555	16%
Thickness of Quaternary aquifer	22,370	55%
Thickness of Silurian/Devonian aquifer	1,836	5%
Transmissivity and hydraulic conductivity	10,248	25%

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